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Issued October 22, 1907.

HAWAII AGRICULTURAL EXPERIMENT STATION.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

BULLETIN No. 15.

CULTIVATION OF TOBACCO IN HAWAII.

BY

JARED G. SMITH,
SPECIAL AGENT IN CHARGE OF HAWAII EXPERIMENT STATION,
AND
CHARLES R. BLACOW,
IN CHARGE OF TOBACCO INVESTIGATIONS.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,
U. S. Department of Agriculture.

WASHINGTON:
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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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ALICE R. THOMPSON, *Assistant Chemist.*

LETTER OF TRANSMITTAL.

HONOLULU, HAWAII, *August 1, 1907.*

SIR: I have the honor to transmit herewith, and recommend for publication as Bulletin No. 15 of this station, a paper on the Cultivation of Tobacco in Hawaii, prepared jointly by myself and Mr. C. R. Blacow. The paper embodies the results of three years' work with this crop in an attempt to demonstrate the possibility of its production on a commercial scale in Hawaii. The small crop produced in 1904 showed excellent characteristics, and these have been greatly accentuated in each succeeding crop. The tobacco is of mild flavor, good burn, elasticity, and texture, the Sumatra and Cuban type of wrapper leaves showing qualities similar to those produced in the best tobacco districts of those countries, so that there is now no question that the industry can be established on a commercial basis.

A point of interest which has not been touched upon in the body of the bulletin is that a few plants from Turkish tobacco seed which came from Asia Minor produced leaf having the characteristic flavor and aroma of this well-known type, and it is believed that considerable areas of land in Hawaii are suitable to the production of this and other scented tobaccos.

Respectfully,

JARED G. SMITH,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON, *Secretary of Agriculture.*

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CULTIVATION OF TOBACCO IN HAWAII.

INTRODUCTION.

The requirements of skill and knowledge attendant upon the curing, fermentation, handling, and marketing of tobacco make the cultivation of this crop one of the most desirable for inculcating thrift as well as modern methods of agriculture. The districts where the soil and climate are adapted to the production of cigar-leaf tobaccos of high grade are limited. For that reason the market for the product is always a good one. While tobacco is, perhaps, strictly speaking, a luxury, it is one of world-wide use among all nations and all classes of people. As in the case of all other luxuries, stimulants, or narcotics, the ratio of consumption depends somewhat upon the prosperity of the people who use it. Tobacco is always salable, but its price rises and falls in accordance with world-wide conditions as affecting the supply of the weed and the purchasing power of the consumer.

The production of tobacco in any country tends toward the building up of a stable population. The skill required is that of men who make its production their life-long occupation. A great deal of labor is required, and if the industry is to succeed here in Hawaii those who are identified with its development must people the land and bend their endeavor to the maintenance of a permanent, contented population.

The tobacco grown by the Hawaii Agricultural Experiment Station in the Hamakua district on the island of Hawaii has been pronounced by experts in the trade as equal in quality to that produced in any other tropical tobacco-growing country. It was believed before the work was begun that this and other districts were particularly adapted to the cultivation of this crop, provided modern methods were applied. Work was begun three years ago with the object of demonstrating the possibility of this crop. The work has been hampered from the beginning by insufficient funds, but the results amply repay for the struggles and hardships. Mr. C. R. Blacow has had entire supervision of the work, under the direction of the special agent in charge, since June, 1905, and the success of

the demonstration has been due to his constant efficiency. Acknowledgments are due to Mr. George P. Thielen, James B. Castle, J. P. Cooke, George N. Wilcox, and A. S. Wilcox, who came to the assistance of the station at a very trying financial period, and contributed $4,000 toward the cost of building a new tobacco barn, and for the payment of other necessary expenses in connection with the experiment. Early in 1906 the land commissioner of Hawaii, Hon. James W. Pratt, reserved from entry for the use of the station, for the purpose of this experiment, lot No. 17, Paauilo homesteads (Pl. I, figs. 1 and 2), this reservation to hold for three years if desired to maintain a demonstration field during that period. The legislature, in 1905, appropriated a sum equal to $228 per month for assistance. A large part of this fund was used for the tobacco work. The remaining portion of the expenses of the experiment have been borne from the regular funds of the station.

Many experiments with the tobacco plant have been undertaken. Seed has been planted every week in the year, and plants have been set in the field in all seasons. Studies have been made of a number of types of Cuban, Sumatra, and domestic tobaccos, and much valuable data has been got together. The station has experimented on the type or style of tobacco barn best suited to Hawaiian conditions. It is believed that the one described on page 9 represents an improvement in the curing barn over any type of structure used in other tobacco countries. This preliminary work, if taken advantage of by anyone entering upon the cultivation of tobacco on a commercial scale in Hawaii, can be made to save a great deal of money.

Demonstration experiments of the possibility of the introduction of new crops are extremely expensive, and the funds of the station will not admit of carrying on these experiments upon the former scale. Some of the problems incidental to the successful growing of tobacco may be continued, but the station turns over to the people of Hawaii the results achieved and will leave to private enterprise the establishment and further development of the tobacco crop.

THE CURING BARN.

The curing barn should be built before planting operations are commenced. A group of buildings should be conveniently located, and here in Hawaii, where the slope of the land is steep, they should be erected at the lower edge of every 100 acres of planted land. Curing barns containing 10,000 cubic yards of space will be necessary for every 100 acres of tobacco, provided the structures are supplied with artificial heat, as should be done. If no artificial heat is provided, it will require buildings with from 18,000 to 20,000 cubic yards of space to care for 100 acres of crop. The buildings

FIG. 1.—LOT 17, PAAUILO TRACT BEFORE CLEARING ABANDONED COFFEE.

FIG. 2.—TOBACCO FIELD PLATS, PAAUILO.

should be of a permanent character. If properly built and provided with proper precautions against destruction by fire, the building should last for at least twenty years, and if properly cared for it will last for a much longer period. The barn should be placed at right angles to the prevailing winds. It is better to erect it on a sloping hillside, provided the slope of the land is toward the direction of the wind.

The curing barns should be frame structures, built of common sizes of northwest lumber. No timbers larger than 4 by 6 inches are required and these only for the sills. A shingle roof is preferable to an iron roof. The barn must be floored. The construction of the ground floor will be discussed later. The wall on the leeward side of the building should extend clear to the ground, also the two ends. This acts as a wind sail for forced draft. Ventilation should be almost entirely through the floor. The building should be from 22 to 24 feet from sill to plate (fig. 3) and 40 to 48 feet in width, with a gable roof. The gable ridge should have a height of 16 feet above the plate, irrespective of the width of the building. The wind-sail method of ventilation is rendered possible because of the uniform trade winds blowing almost continuously throughout the year. The experiment station has tried buildings with different systems of ventilation, and it is believed that for Hawaiian conditions the method here recommended is the best. The roof of the barn should be constructed with an open ventilator in the ridge. The cheapest and most practicable ventilator is the one which is figured in the accompanying plans (figs. 1, 2, 3, and 4); that is, the windward roof should project 3 feet over the lee roof, with a swinging door 18 to 24 inches in width the whole length of the building. This swinging door should be hinged on the bottom and an arrangement of ropes and pulleys provided so it can be opened and closed at will. No other ventilators are required in any part of the building. This applies to tobacco barns in the windward districts of Hawaii. In other localities not subject to the trade winds horizontal side ventilators of similar construction should be placed just below each of the stall floors.

If a single building with a capacity equal to 100 acres of crop is built, it should be divided into five compartments by partitions from the ground to the roof. Each compartment may be considered as a unit, and this unit construction may be followed for a single barn if it is decided to erect a number of smaller structures in separate localities rather than a single large one. There should be a 4-foot passageway down the middle of the whole length of the building, this passageway extending from the floor to the roof. Each unit should contain three double sets of hanging stalls on each side of the passage. The first floor should be solid, except that a ventilator—composed of two 1 by 6

inch boards, hinged on their outer edges, open from the center upward, an arrangement controlling the size of the opening and regu-

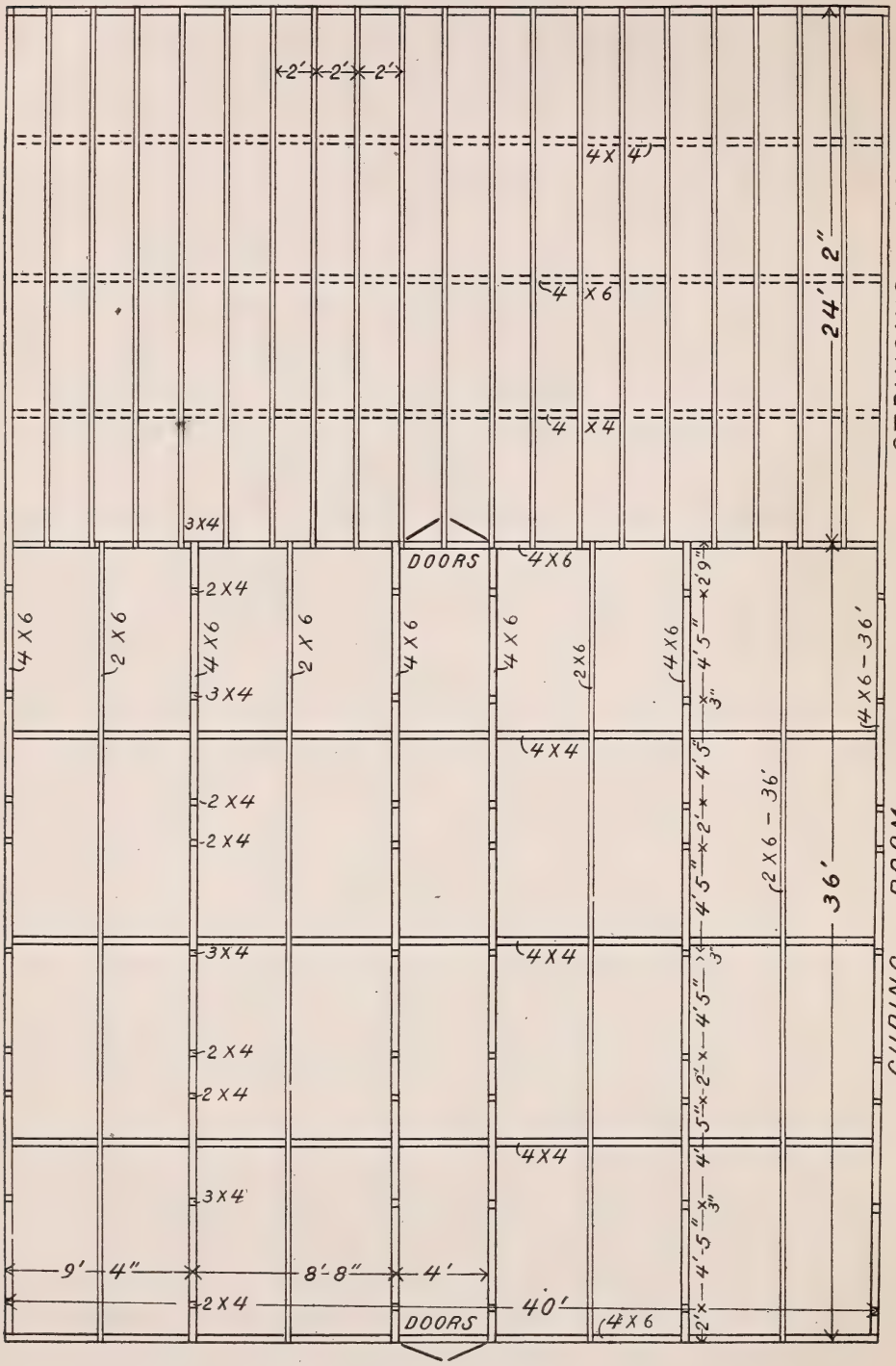
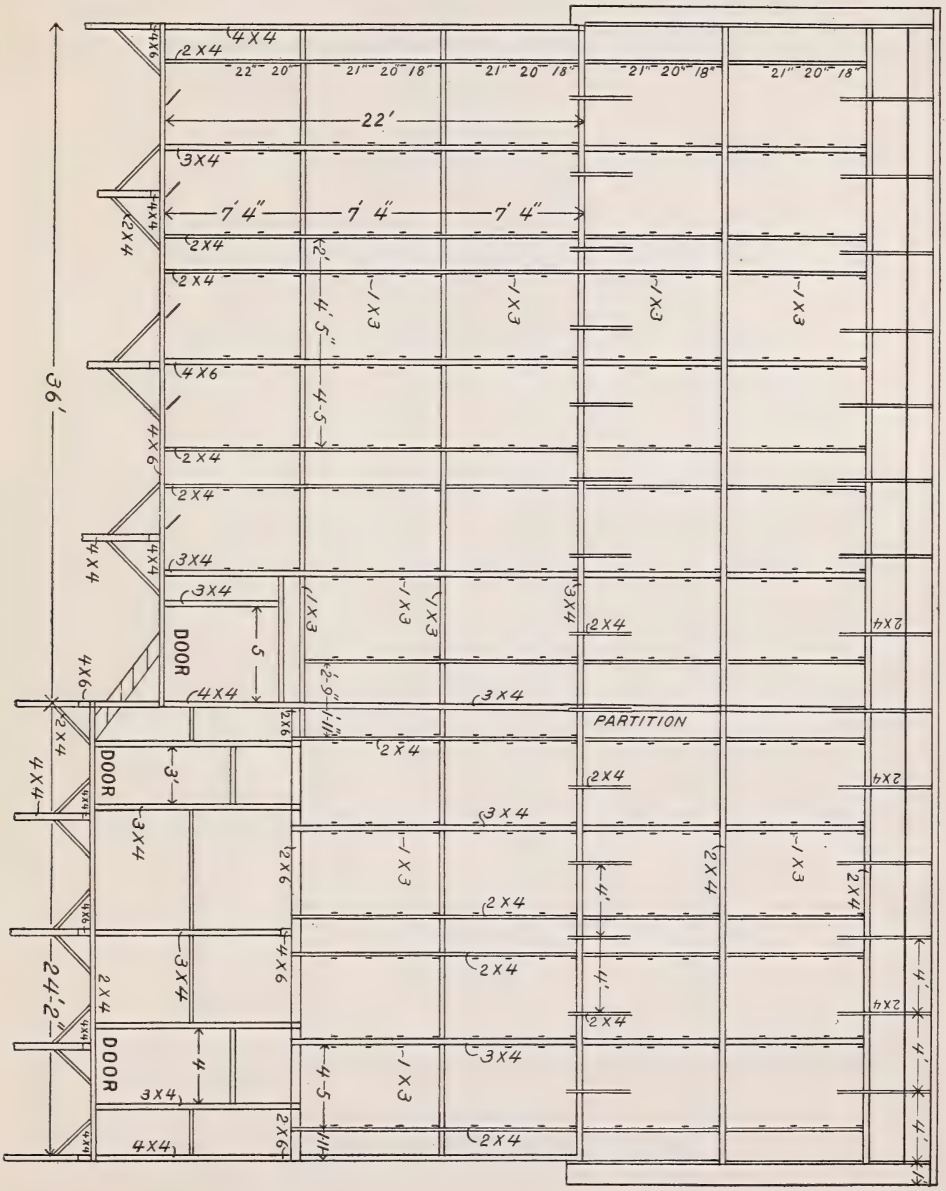


FIG. 1.—Ground plan of tobacco barn.

lating the draft—should be built immediately under the center of each tobacco stall. Starting at one end of the building a 2-foot alley-

way is left next the end wall. Then two 4½-foot skeleton stalls are framed of 2 by 4 inch stuff and four hanging rails at equal distances apart are nailed on the sides. Then there is another 2-foot passageway, and another double set of stalls, and so on to the other end of the building, finishing with a 2-foot passageway between the last


36'
22'
7' 4"
7' 4"
7' 4"
4' 5"
4-5
5
DOOR
DOOR
DOOR
3'
4
24'2"
PARTITION
4'
4'
4'

inch board laid in the passageway between the stalls and in the middle of each stall upon which the person hanging the tobacco walks. The height of the building is divided into three floors, with two floors in the gable. The floors can be connected by stairs or an elevator. Each unit should contain about 2,000 cubic yards of space. This size unit will accommodate the crop of from 5 to 6 acres of tobacco without artificial heat, which capacity is doubled if artificial

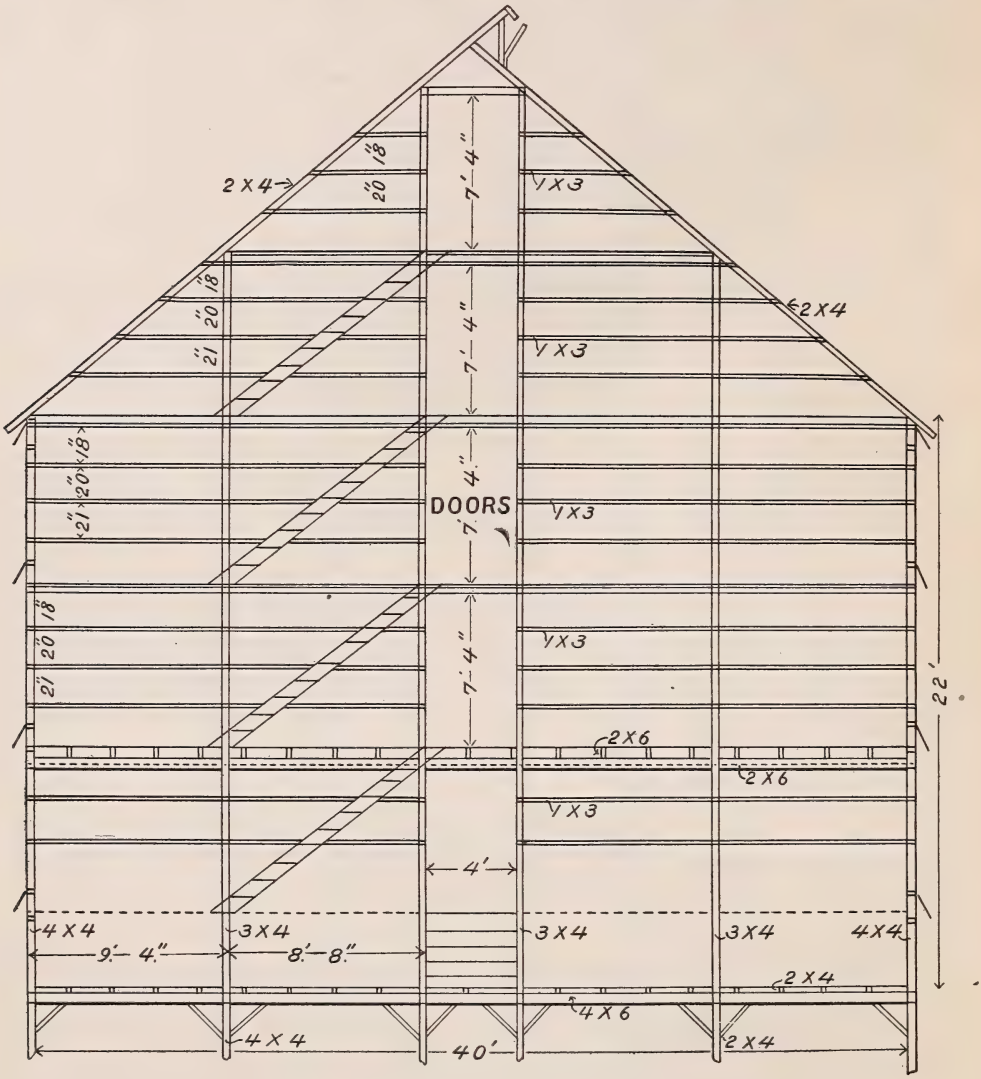


FIG. 3.—End elevation of tobacco barn.

heat is used; and, as about one-fourth of the crop is harvested at a picking, 5 units will care for 100 acres of crop with artificial heat, but 10 units will be necessary if no such heat is provided.

The heating plant should be hot water or steam, preferably the latter. Flue heating is not safe. There is danger of fire, and the heat is not controllable as in the case of either water or steam. The pipes should be placed on the first floor only.

In addition to the curing barn there must be a stringing room, which may be a lean-to of sufficient size, as experience will direct, attached to one end of the building (fig. 1).

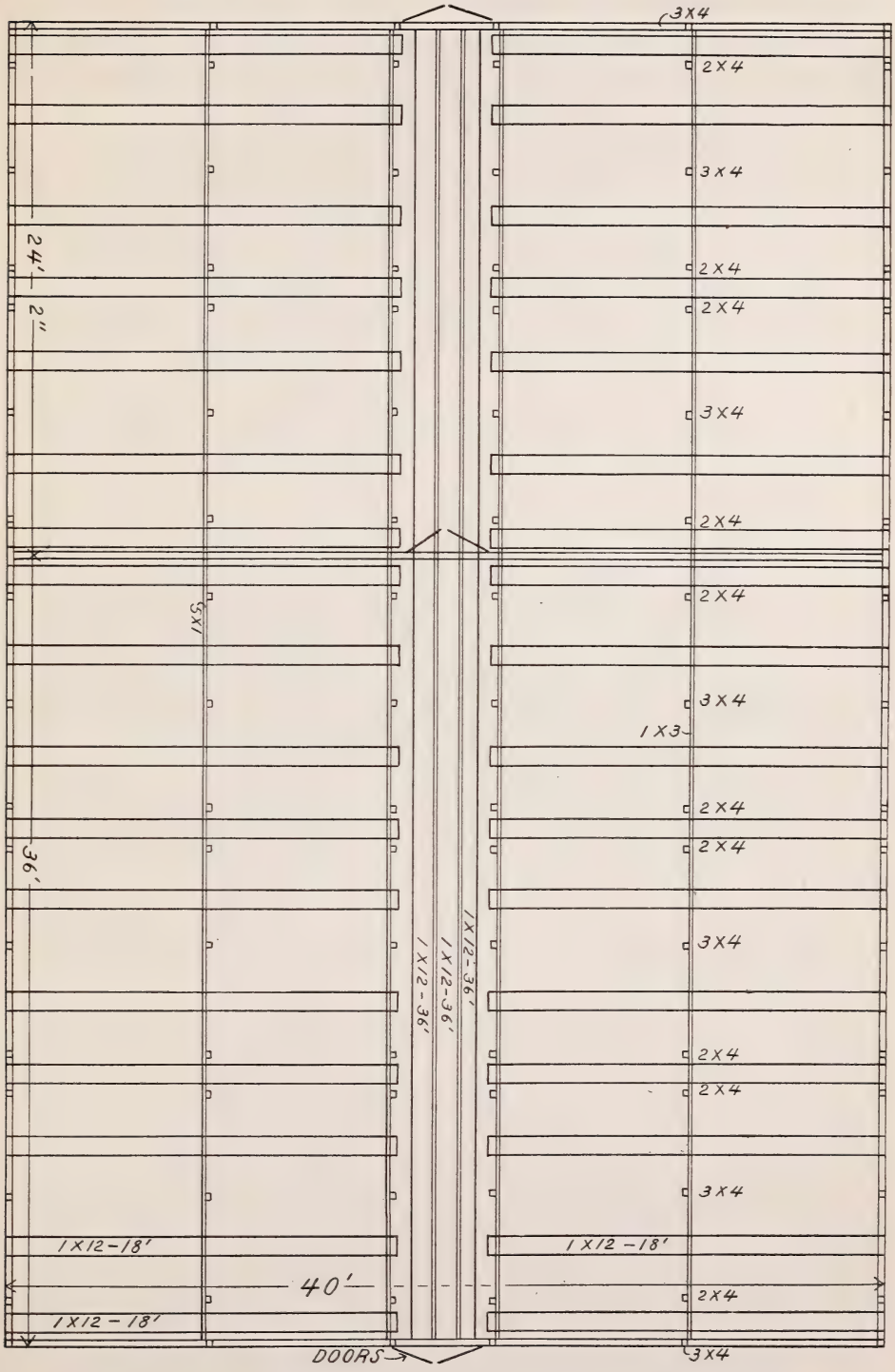


FIG. 4.—Skeleton hanging floors of tobacco barn.

Another necessary building will be a fermenting room, but this can be located at any convenient place on the plantation, the product being taken to it from all the curing barns at the end of the campaign or at a convenient season.

The stringing room should be well lighted and well ventilated, and should be provided with a number of single stalls, arranged with hanging rails, as in the main body of the curing barn.

The fermenting room should be well constructed, with tight floor and tight walls, absolutely under control as to heat, moisture, and ventilation. Near the fermenting room should be a well-lighted and well-ventilated sorting room with large table space, the temperature and moisture under control, in which the tobacco is finally assorted, graded, and classed for baling after the fermentation is completed. A suitable press for baling should be provided in the fermenting room.

These buildings are absolutely necessary if it is desired to produce tobacco of good quality, and they should be provided before the crop is started.

THE SEED BEDS.

The seed beds should be made of 1-inch redwood lumber, 12 feet long, 4 feet wide, and 10 inches deep, provided with gable ends having an angle of 45°. A slot 1 inch by 3 inches should be cut in the apex of each gable end to permit the insertion of a movable ridgepole 1 inch by 3 inches wide and 13 feet long. A strip of muslin 36 inches wide should be fastened by one edge to each side of the ridgepole and a slat about 1 inch by $1\frac{1}{2}$ inches cross section tacked to the lower edge of each piece of muslin. The strips of muslin should be 13 feet long. This constitutes the covering of the seed bed. The advantage of its use is that it can be rolled up when the seed beds are empty, removed to admit sunlight, or either side thrown back over the ridgepole to permit partial exposure in hardening the plants before transplanting.

The soil for the seed beds should be sterilized previous to use. A cheap apparatus for sterilizing soil where live steam is not obtainable is a rectangular box or trough of redwood planks, the bottom of which is made of No. 10 gauge sheet iron. Fasten the iron securely to the bottom of the sides and lead the joints with a mixture of white lead and red lead or steam-fitters' putty. About 4 inches above the sheet-iron bottom of the trough fit in a loose false bottom to sustain the weight of the soil and prevent the dirt falling through to the bottom of the trough. This trough should rest on stone or iron legs about 14 inches from the ground, so that a fire can be built underneath. When ready for use fill the trough with water up to about the level of the false bottom, insert the false bottom, and fill the

trough with the earth which is to be sterilized. Then build a fire underneath and heat until the soil has been thoroughly steamed. The sterilizing process should be continued until the top soil shows a temperature of 200° F.

The soil for the seed beds should be the richest that is obtainable, either leaf mold from the forest or silt from the rich pockets in the gulches, or a compost mixture of grass turf. The richer the soil used in the seed beds the better start the young plants will have before transplanting. It is very important, especially in the cultivation of tobaccos of the finer wrapper types, that the plant should be forced through its entire period of growth, both in and out of the seed bed. The impetus which the young plants get in the seed bed is probably of greater importance than any later efforts to force growth after they have been set in the field. After the tobacco plantation has become established it will pay to prepare each year a compost heap in anticipation of the next year's sowing.

The seed beds should be out of doors. The results of our experiments indicate that seed beds, such as those above described, are much better than either cloth seed houses or open seed beds without cloth cover. If the seed beds are made of redwood their durability will be prolonged from six to ten years, and they should be constructed in such numbers as experience shows to be necessary. There is an advantage in having all the seed beds in one place on account of convenience in watering and caring for them. Enough seed beds should be prepared so that a planting can be made at least once a week during the entire season. This is very important. In fact, it is one of the most important precautions for successful tobacco plantations that there shall be a continuous supply of seedlings at all seasons throughout the year, even though many of the plants are wasted.

Planting the seed consists of scattering it thinly over the surface of the seed beds. Four teaspoonfuls of seed are enough for 40 square yards of seed bed. It is customary to mix the seed with dry wood ashes, which serves the purpose of showing where the seed has been sown. Tobacco seed is so minute that it is almost impossible to scatter it thin enough without a liberal mixture of ashes or some other indicator. The seed of the Cuban varieties is very small, that of the Sumatra varieties a little larger, and that of the seed leaf and other American types larger than either.

Before sowing, the seed should be winnowed to remove all light and immature seed. Only the largest seed should be used. The seed may be winnowed by the use of a bicycle pump or a blast-lamp bellows, attached by a rubber hose to a vertical pipe or tube, open at its upper end. The vertical pipe is about 30 inches high. The tobacco seed is placed in this or is poured into the top while the

blast is in operation. The light seed is blown out and the heavier seed falls to the bottom of the tube.

After the seeds are sown they should be watered, using a watering pot with very fine rose, and the bed will have received enough water when the color of the ashes has disappeared. No covering of soil should be placed over the seed. Germination occurs in from eight to twelve days. The young plants are extremely minute, and the growth is very slow for at least a week. The surface of the seed bed should never be allowed to dry out, but the bed should not be soaked. This will require close attention on the part of whoever attends to the seed beds.

SEED-BED ENEMIES.

The enemies of the tobacco plants in the seed beds are slugs, flea-beetles, and the damping-off fungus. If the seed beds are in the field or open land cutworms are sometimes a serious pest.

Slugs or snails are nocturnal enemies. They destroy the seedlings in all stages of growth. Slugs hide in the daytime under boards or stones, or in the loose earth, near the seed beds. The best remedies against slugs are common salt and lime. If wooden frames are used the paths between the seed beds should be sprinkled with coarse salt.

If sterilized soil is used in the seed beds there will not be much trouble with flea-beetles, but if unsterilized soil is used these are found to be quite destructive. The best remedy is the use of water. Keep the seed bed moist. If allowed to dry out it is not only bad for the young plants, but supplies favorable conditions for the rapid increase in the number of flea-beetles.

Sterilizing the soil will prevent loss from the damping-off fungus, *Rhizoctonia* sp. This fungus is prevalent in Hawaiian soils, especially in the windward districts. It is a parasitic disease of the seedlings of almost all plants. If unsterilized soil is used the only remedy to check the spread of the damping-off fungus, when an outbreak occurs, is to spray the soil with a 3 per cent solution of formalin, or with Bordeaux mixture. A mixture of 3 ounces of flowers of sulphur, 4 ounces of finely powdered copper sulphate, and 14 pounds finely sifted air-slaked lime, thoroughly mixed, dusted over the seed bed with a fine-meshed cloth bag has been found effective as a check against this fungus. If flea-beetles are prevalent add to the mixture 2½ ounces of Paris green.

The remedy for cutworms is poisoning at frequent intervals with a mixture of bran, sugar, and Paris green. This should be scattered over the seed beds in the evening, as cutworms feed almost entirely at night.

Another pest which sometimes causes serious loss is the club root, a disease caused by microscopic worms called nematodes, which bur-

row into and feed upon the living tissues of the roots of the tobacco plant, causing the root to swell up, rot, and decay. In the seed bed there is no known remedy for nematode worms, but cultivation and the drying out that follows thorough aeration, materially decreases their numbers. The only sure method of preventing these pests in the seed beds is to sterilize the soil.

The seedlings should be ready to transplant to the field in from seven to ten weeks from the time the seed is sown. There is no hard and fast time limit. If the season is favorable, and the seed beds are located where the exposure is toward the south, or southwest, with protection from winds, and all conditions are favorable for growth, the plant will be ready to set out in the field within six weeks after germination. If a constant supply of seedlings is maintained by consecutive plantings, the best rule to follow will be that of experience. Select only strong, vigorous, stocky plants, and do not transplant any seedlings which have commenced to shoot up their main stalk. A setback is unavoidable, and seedlings that have begun to make a stalk do not show the same vitality in aftergrowth. The plants should have the advantage of sunshine and full exposure to the air for a week before planting, to harden them off.

FIELD PREPARATION AND TRANSPLANTING.

The tobacco plant is a strong and vigorous grower when once its roots become firmly estabished. Therefore the soil must be in the very best of tilth, because the quality of the tobacco in the field depends on having an abundance of plant food readily available for its use during the entire growing period. The soil should be plowed at least six months before it is ready to plant. Tobacco has a taproot which goes down as deep as the soil is mellow. This taproot is an anchor. The lateral roots are all in the top 6 inches, therefore the fertilizer should not be applied until after the first plowing. The first application of fertilizer should be air-slaked lime, at the rate of 1 barrel (200 pounds) per acre. This need not be cultivated into the soil, as the soluble portion will be carried down through and into the soil by the rains. From three to four months after the first plowing the land should be cross plowed. A dressing of 200 pounds of sulphate of potash and either 400 to 600 pounds of fine-ground raw phosphate (floats or South Carolina rock) or 200 pounds of Thomas slag, should be broadcasted over the field and harrowed in. The second cross plowing should be two or three months before the crop is transplanted. No weeds should be allowed to grow on the land after the first plowing, because these would supply food for cutworms. Clean cultivation is the best remedy for

cutworms. If, however, the weeds have been allowed to grow, the poison-bran mixture recommended above should be broadcasted over the field at least twice within the last month, the last application from three to five days before transplanting. The land should be given a final harrowing within a week before the plants are set in the field.

The first operation of transplanting is to line the field. The lines should be as nearly as possible on contours, so that the wash will be at right angles to the rows across the field. The rows should be 42 inches apart for Cuban and Sumatra, and 48 inches for seed-leaf, manufacturing, or any other domestic tobaccos. At the time of transplanting apply 200 pounds of high-grade fertilizer of approximate composition of phosphoric acid 7, potash 10, and nitrogen 7 per cent; half of the nitrogen in the form of nitrate of soda and half as dried blood or cotton-seed meal. The phosphoric acid should be in soluble form, preferably superphosphate. The potash should not be in chlorid form as chlorin is very detrimental to the burning qualities of tobacco.

The preliminary application of low-grade potash and phosphoric acid would not need to be repeated until several crops had been grown on the same land, but the application of high-grade fertilizer in the row should be applied to every crop.

The tobacco plants should be transplanted on cloudy days or during light rains, or, if no cloudy weather prevails, late in the afternoon. The first cultivations can be done by machinery and horse labor, but after the plant is well established the danger from leaf breakage and disturbance of the surface roots forbids any other cultivation than shallow hoeing. Set the plants level with the surface of the soil and hill up afterwards. Both the Cuban and Sumatra types should be set about 15 inches apart in the row; the seed-leaf, manufacturing, and other domestic types, 24 inches in the row. Replanting should be carried on within thirty days, and every effort made to obtain a full stand. Transplanting can be successfully done with machinery, but replanting must be done by hand. A modern transplanting machine, with a team, driver, and two men, will set and water from 2 to 6 acres of tobacco plants a day. Cultivation should cease within sixty days after the plants are set in the field. The general rule is to discontinue cultivation at topping time. If machinery is not available for setting the plants it will require from 5 to 7 laborers to transplant an acre of tobacco a day. A full stand, at the distance provided for—that is, 42 by 15 inches—will be about 10,000 plants per acre.

TOPPING AND SUCKERING.

The tobacco should be topped after a certain period of growth, which can only be determined by field experience. The nature of the plant being to reproduce itself, a flower bud appears. If left to grow it will branch, flower, and bear eventually a large number of seed pods and innumerable seeds. If the plant is permitted to flower it destroys the value of the leaf. As soon as the flower bud appears and can be removed without injury to the young and tender leaves at its base it must be pinched out with the thumb and finger. The terminal flower bud having been taken out, the plant will produce lateral branches from the axils of the upper leaves. These must be in turn removed without injury to the leaves. This removal of the flower bud creates a diseased or abnormal condition in the plant, and this diseased condition, artificially produced, governs the whole curing and fermentation process after the leaf is harvested. Leaves from plants which have been permitted to flower or produce seeds can neither be properly cured or fermented, and the product from such is woody and worthless. The crop is not tobacco unless the topping and suckering is rigidly carried out. The quality of the tobacco in the market depends in a large measure upon this manipulation in the field.

HARVESTING THE LEAF.

There is no hard and fast rule to indicate when the leaf is ripe. It is largely a matter of judgment to be determined by long practice and experience. The harvesting of the crop requires a great deal of skill, knowledge, and judgment.

The first selection of wrapper, binder, and filler is made on the plant. The wrapper grades, being the highest priced tobacco in the market, demand the greatest skill in selection. Wrapper tobacco should be harvested underripe to preserve the elasticity, and obtain the light colors, which present trade requirements demand. The three grades—wrapper, binder, and filler—should not be harvested at the same time, but each should be taken from the plant separately. Leaves that would have been suitable for wrapper, but which have in any way become broken or injured, should be left on the plant to produce filler. It will not do to harvest broken wrapper leaves and treat them as such. Binder, which consists of the intermediate grade between wrapper and filler, can be allowed to become thicker than the wrapper quality. All other leaves at maturity become filler. None of these grades should be permitted to go past maturity. It is better to harvest underripe than overripe. The harvesting can be carried on in any weather in Hawaii, whether rain or sunshine.

As the leaves are removed from the plant they should be placed in baskets or other light receptacles and taken without delay to the stringing room, where each grade should be kept separate and roughly assorted to length. The fresh leaf should never be piled in deep piles, as it heats very rapidly, and such heating has a tendency to turn the leaf black. It does not harm the leaf to wilt, but it must not be allowed to heat. Having reached the stringing room, and having been roughly assorted to length, from 50 to 60 leaves are strung with a straight needle and cotton thread, back to back and front to front, about an inch apart. The distance between the leaves is readily gauged with the fingers. The string is knotted at one end only. A string of leaves when completed is ready to put on the pole. The tobacco pole is a lath 4½ feet long, ⅝ by 1 inch, sawn out of rough 1 by 12 inch lumber, with a saw scarf at each end cut to a depth of about three-fourths of an inch. When the leaves are strung the knotted end of the string is fastened in the scarf at one end of the pole, the string is pulled tight, passed through the scarf at the other end of the pole, and fastened by weaving in and out. One pound of string is enough for 200 poles. The string should be cut 10 feet 8 inches long, and doubled.

The tobacco is now ready to be placed upon the racks in the curing barn. A barn of the type here recommended should be filled from the bottom upward, so that the green tobacco is always on top, and never below that which is partially cured. The air is essentially humid in the tobacco barn, and it is detrimental to have an ascending current of wet air passing through the tobacco which is partially cured. The poles should be placed at an average distance of about 9 inches apart on the hanging rails, so that the leaves will not touch. It is very important that the leaves should not touch while hanging.

THE CURING PROCESS.

The tobacco crop should be large enough so that a unit of the curing barn can be filled with one grade of tobacco, either wrapper, binder, or filler, in the shortest possible time. This filling of the barn may be allowed to extend from two to three days, but it will be advantageous to fill the unit in a shorter time if possible.

The cure depends upon the exclusion of light, thorough ventilation, and perfect control of temperatures and humidity.

A diseased condition having been produced in the leaf in the field by the topping and suckering process, by which the amount of enzyms in the plant cells are greatly increased, the object of curing is to produce a yellowing in the leaf by prolonging the death of the green cells in the leaf. The yellow color is essential. Without it the leaf cures black. If the leaf dries too rapidly, and yellowing does not occur, it cures green. The whole curing process is a delicate one,

requiring constant vigilance. The control of temperatures, ventilation, and humidity are a matter of practice which will have to be determined in each locality. In general, the temperatures should remain low until the leaf has wilted and should never be allowed to go so high as to set the green color in the leaf. The temperature should exceed humidity from 10° to 15°. If the degree of humidity approaches nearer to that of the temperature, pole rot, stem rot, white vein, molds, and other maladies of the curing barn can not be kept out. In 1906 it is said that 20 per cent of the whole tobacco crop of the United States was affected from these causes. In a humid climate like that of Hawaii artificial heat in the curing barn is absolutely essential for this cause alone, even if its possession did not double the capacity of the curing plant.

As soon as the web of the leaf has passed from the yellow into the brown, the temperature should be greatly increased in order to dry out the stem and veins. The heat does not injure the leaf after the color is once set. As soon as the veins are dry, or as soon as the green coloring has disappeared in them, the leaf is cured and is ready for removal. With artificial heat the curing process may be finished in from twelve to fourteen days. Without heat it will require twenty-four to twenty-eight days. Artificial heat in the curing barn is an insurance and is a very important part of the investment. It insures even color, freedom from disease, and doubles the capacity of the establishment. The tobacco is now ready to take down, assort, and bundle for fermentation. After the unit is emptied it is ready immediately for a new filling. The tobacco will keep in the pile better than it will hanging in the barn on account of danger of molds should a period of wet weather ensue.

SORTING AND BUNDLING.

The tobacco having been taken on the poles to the sorting room, the poles are bunched close in storage stalls of a construction similar to those in the curing barn. Before the leaf is removed from the string it should be roughly sorted into thin, medium, and thick leaves, all damaged leaves being placed with the filler leaves irrespective of thickness. If the tobacco on the pole is mainly thin leaves, the medium and thick or broken leaves should be stripped from the string, and vice versa, care being taken not to tear or break the leaf in pulling it off the pole. The thin, medium, and thick leaves should be placed in separate compartments. The pole having been culled, the string is taken off the pole and the leaves drawn off from it. As rapidly as assorted, the different grades should be bundled into hands. A hand consists of from 50 to 100 or more leaves. The stems are gathered in the palm of the hand between the thumb and

forefinger, all butts being kept even. When the hand is from 2 to 3 inches in diameter, it is tied by bringing one leaf up over and twisting it around the butts, the loose end being tucked into the hand. As soon as from 1,000 to 1,500 pounds of tobacco of any one grade has been assorted, it is ready to ferment.

When taken from the curing barn to the sorting room, the tobacco should be moist. If the weather is cloudy or rainy, no artificial additional moisture will be necessary, but in a dry period, or when the humidity is low, the tobacco can be moistened by wetting down the walls and floor of the sorting room, or by turning live steam in the room, in case a steam plant has been provided. The tobacco must never be sprayed or any direct application of water made to it. A properly cured leaf absorbs moisture from the air with great rapidity and will hold from 20 to 25 per cent of moisture without detriment. This is about the amount it should contain when placed in the fermenting heap.

FERMENTING.

The fermentation should follow immediately after the grading and sorting process, as the tobacco is then in the best condition. A much better fermentation can be secured immediately than after a delay of weeks or months. The tobacco is taken from the assorting room to the fermenting room. The fermenting room is provided with platforms 5 feet wide and of sufficient length to hold from 1,000 to 1,500 pounds. These platforms are raised a foot above the floor and should have a bulkhead at each end, about 5 feet high. The platforms are covered with cotton cloth, burlaps, or some other cheap material to keep the tobacco from coming in contact with the lumber of which the platforms are constructed. To build up a bulk or fermenting heap the hands are laid close in 4 or 5 rows until the bottom is completely covered, the butts overlapping the tops about a third of the length of the leaf, and subsequent tiers are added until the quantity at hand is all in the pile. A tin or copper pipe, about 2 inches in diameter, closed at one end, should be stood in the center of the pile and the tobacco built up around it. This tube should be long enough to reach above the top of the pile of tobacco, and the open end is placed up. This pipe is to be used for a thermometer, which can be lowered to a position corresponding with the bottom, middle, or top of the pile. If the tobacco is in proper case when it is placed in the pile—that is, if the leaf contains 20 to 25 per cent of moisture—a rise in temperature will begin at once. The fermenting heap when finished should be covered over with a tarpaulin or rubber blanket, excluding all air and retaining all moisture. No weight should be applied. When the building of the fermenting heap is finished the temperature of the room should be raised

from 8° to 10° above the temperature of the pile until the temperature of the pile becomes equal to that of the room. In the tobacco districts of Hawaii the summer air temperatures are about 65° to 75° inside the buildings. The fermenting room should be heated to from 85° to 95° and should be kept at that temperature until the temperature of the pile of fermenting tobacco equals the temperature of the room. As the temperature in the fermenting pile of tobacco increases above 90°, the air temperature should be permitted to remain about 10° lower than the increasing temperature of the pile.

Wrapper, binder, and filler tobaccos require different treatment in fermenting, the best wrapper tobaccos being produced at lower temperatures than fillers. The higher the temperatures in the fermenting pile the darker the color of the finished leaf. Under no circumstances must the temperature of the fermenting tobacco be permitted to rise above 136° F. As soon as the temperature in the middle of the pile, which is the hottest, reaches 100° F., the pile should be torn down and rearranged on an adjoining platform. The bottoms, sides, and tops are placed in the center of the new pile, and the center of the first pile becomes the outsides, bottoms, and tops of the second pile. This process should be continued throughout the various rebulkings.

Indications are that the best qualities of wrapper leaf should not be allowed to go much over 100° F. If light colors are shown—that is, if the color of the leaf is desirable—fermentation may be reduced to a minimum, which will mean that the pile will have to be rebulked perhaps every twenty-four hours. An important point is to maintain a constant degree of humidity in the fermenting room. The air in the fermenting room should never be permitted to become dry, but should always show from 85° to 90° of humidity, irrespective of the temperature. In wrapper tobacco color is everything. As the piles are broken down and rebulked there is each time a slower rise in temperature, and it is a matter of judgment as to when the fermenting process should be discontinued. When the stage is reached where the temperature of the tobacco in the pile rises, remains stationary, and then begins to fall, the fermentation is finished.

Binder tobacco will stand more fermentation than wrapper. Thick wrapper will stand more fermentation than medium wrapper, and both than the thinnest or highest quality of leaf. The better the quality of the tobacco the greater care should be exerciesd in its manipulation. In the case of filler tobacco it is best to allow the temperature to approach the maximum limit of 136° at the second turning, the subsequent rebulkings being checked at lower temperatures. In the first stages of fermentation large quantities of ammonia are set free,

and there is a considerable evolution of ammonia throughout the whole fermentation process. As soon as the fermentation is complete the tobacco is ready for the final sorting.

SORTING TO COLOR AND PREPARATION FOR BALING.

From the fermenting room the fermented tobacco is again taken, in such quantities as will not dry out, to the sorting room, which, as in the case of the one previously used, should be well lighted, ventilated, and so arranged that it can be kept moist. A good arrangement of this assorting room would be with north light along the whole side of the building. Direct sunshine or southern exposure is very detrimental. The sorting tables should be at right angles to the source of light, the sorters with their sides toward the window. This final sorting is the most important stage in the whole process of treatment of the tobacco leaf. The leaf must be graded to color, shape, thinness, and length, and requires a class of labor of the very highest skill. Wrapper tobacco of the Sumatra types is graded into seventy-two classes. There should be at least six colors of wrappers—dark, brown, light, green, specked, and broken. They should be graded to length, so that there should not be a variation of more than 2 inches in the length of leaf in any lot. Gradations of color can best be determined under north light. A final separation should also be made to thick, thin, and medium leaves. The more perfectly this final separation and assortment is made the higher will be the prices obtained for the crop. It is well to remember that *the selling price of a bale of tobacco is governed by the quality of the lowest grade in the bale*, and when finally prepared for marketing each bale must be marked to indicate what the lowest grade in the bale is, and the mark on the outside of the bale must be true.

After this final sorting has been completed the tobacco should again be made up into hands of smaller size, not to exceed from 1 inch to 1½ inches in diameter at the butts. No leaf should be placed flat in the hand whether previous to fermentation or previous to baling. It must be opened and flattened by the sorter to determine the size, color, shape, and other characteristics, but when these are determined the leaf should be drawn through the fingers to close it back to its natural condition. Great care should be exercised in forming the hand of the finally assorted tobacco, because the neatness of the bundle always adds to the attractiveness and selling price.

BALING.

The size of the tobacco bale varies according to the type of the tobacco. The weight of the Sumatra tobacco bale varies from 175 to 200 pounds, the Cuban from 90 to 100 pounds. The bale of either

type should be about a foot in thickness after being compressed. The other dimensions depend in some measure upon what tobacco is available, long leaves requiring bales of larger size than a smaller average leaf. Every tobacco company should adopt a standard and adhere to it.

A second fermentation takes place in the bale. It is a slower one and the temperatures do not rise very high, but it seems to be quite important in fixing character in the leaf. This second fermentation mellows the tobacco and tends to improve the aroma. The bales should be placed in the warehouse for at least six months before selling. The warehouse should be clean, dry, and cool, and no other goods stored with the tobacco. Tobacco very readily absorbs bad odors, and may be ruined by lack of cleanliness at any stage in its curing, fermenting, or warehousing. In the warehouse the bales should not be piled in tiers of more than four or five deep, and should be occasionally handled over and examined to see that moisture conditions are right. Even in the bale there is still danger of loss through too much moisture.

Every ounce of tobacco leaf is salable. There is absolutely no waste in this crop from the time when the tobacco is gathered in the field. Even moldy tobacco if baled by itself has value, and can be disposed of at prices which will pay for the handling.

MARKETING.

Tobacco is always sold on sample, and, needless to say, the quality of the tobacco in the bale must correspond to that of the sample. It is well again to emphasize the point that the value of the lowest grade, quality, or size of tobacco in the bale governs the selling price of the whole bale. Five pounds of filler tobacco in a bale of wrapper leaf will make the whole bale filler when valued by any tobacco broker, although, of course, the manufacturer reaps the full benefit.

When the tobacco is ready to market it should be insured and every precaution adopted to keep it from getting wet. In the early years of the industry it will undoubtedly have to be shipped to the New York or other markets, but when the tobacco is once established every pound of it can be sold on the plantation.

CAPITAL REQUIREMENTS.

Anyone undertaking the cultivation of tobacco in this or any other country must have all his equipment of land and buildings ready before even a single acre of tobacco is planted. Tobacco brooks no delay. Wrapper tobacco is of the highest price, and every effort should, therefore, tend toward producing as large a crop of wrapper and of as good a quality as the soil and climate will permit. When

the necessary equipment has been prepared, the field operations may be begun. To do things the other way round is to risk the whole investment, for tobacco is not tobacco unless it is properly handled. The best Partidos, Cuban wrappers, and the plants producing Deli or other famous Sumatra types, are forced from the time the young plant makes its appearance in the seed bed. On the best Cuban plantations the plants are watered in the field every three or four days during the whole growing period. That plant which grows the most rapidly, other things being equal, will produce the best leaf, and of two plants set side by side, the one forced and the other not, that which is forced will produce the greatest percentage of wrapper leaves on the plant.

To grade the leaf and cure it requires a heavy investment of capital, but the growing of the leaf alone is an ideal occupation for a farmer of small means. It is becoming customary in Florida and other tobacco-producing sections of the United States for the larger growers, who control the curing barns and operate the fermenting and assorting establishments, to purchase the green leaves from small producers. The value of the finished product is sufficient to enable the larger tobacco grower to cultivate his small neighbor by paying good prices for the leaf. In fact, it is to their interests to do so. The greater the acreage of tobacco planted in any section, the greater will be the stock from which to select grades of the highest quality.

It is, furthermore, an advantage—even more than that, a necessity—that every tobacco-producing section should have a large permanent population from which to draw labor, and the individuals of that community should be landowners. The crop calls for a great deal of labor, and when labor is required it can not be put off. Wrapper tobacco which is allowed to become overripe will not make good wrappers and is not salable as such. Sumatra wrapper tobacco of the best lengths and light colors cost $4 per pound laid down in New York in April, 1907, whereas prime domestic filler was obtainable at from 15 to 20 cents per pound. This relative proportion between filler and wrapper almost always prevails, so that every effort must be made to force the tobacco plant to make wrapper leaves, and to so cultivate, cure, and ferment that the largest proportion of wrapper shall be of suitable colors, sizes, and texture. The rewards of the successful cultivator are greater than in almost any other agricultural crop.

On account of the fact that the enemies of the cultivated crop increase rapidly with each successive cultivation on the same land, it is highly desirable that the land should be occasionally allowed to rest. Hence, to grow an annual crop of 100 acres of tobacco the planter should own or have available, if required, from 250 to 350 acres.

FIG. 1.—CUBAN VUELTA ABAJO.

Leaves 16 to 30 inches long.

FIG. 2.—CUBAN FILLER.

Plant produced ¼ pound cured tobacco.

FIG. 3.—MANILA TOBACCO.

Leaves 12 to 26 inches long.

FIG. 1.—CUBAN TOBACCO.

FIG. 2.—SUMATRA TOBACCO.

FIG. 3.—SUMATRA TOBACCO, BELGIAN TYPE.

YIELDS.

The yield of tobacco varies according to the variety, the season, the time of planting, and the quality or grade of the type which comprises the majority of the crop. Cuban filler tobaccos (Pl. II, fig. 2)—that is, plants grown from the seeds brought directly over from Cuba—yield from 600 to 1,200 pounds of leaf. Sumatra tobaccos (Pl. III, figs. 2 and 3), brought directly over from Sumatra, will yield from 900 to 1,200 pounds. Cuban tobacco which has been grown two or three years, or more, in Hawaii yields from 900 to 1,400 pounds, while the second, third, and succeeding generations of Sumatra type grown in Hawaii yield from 1,200 to 2,000 pounds. All of these types show improvement in quality when grown under Hawaiian conditions. The results of three years' experimental work with tobacco in Hamakua show a remarkable increase in the percentage of wrapper leaves the third year over that produced by plants grown from seed imported direct from either Cuba or Sumatra. With full stands and favorable seasons, it is believed that 30 per cent of either the Cuban or Sumatra tobacco (Pl. III) will produce high grade wrappers, and this percentage can be materially increased. While there is a wide variation in prices for the different grades of tobacco, this crop differs from most others in that not a single ounce is produced that is not salable, provided they are carefully separated from the better grades. It is believed that for many reasons it will not be profitable to cure tobacco and sell the crop in bulk without sorting or fermenting, as is the custom in most of the mainland districts. Hawaiian tobacco is a tropical tobacco, and direct competition will come with countries in which the last assortment is made on the plantation where the crop is grown. By adopting this system only the best grades should be shipped to the best markets, and the seconds manufactured at home.

SOILS AND CLIMATE.

The characteristics of the tobacco soil were discussed in a previous publication of this station.[a] It is only necessary to recapitulate by saying that the tobacco soil should be light, porous, well drained, with a large percentage of humus. This characterization fits almost all Hawaiian soils, and it is our opinion that tobacco can be grown practically all over the group.

With tobacco, as with all other plants, sunshine tends to thicken the leaf and contract its size, while shade or partial shade tends to produce a larger leaf of great thinness. Tobacco-growing regions where the sunshine is excessive produce only filler tobacco. The

[a] Hawaiian Sta. Press. Bul. 12.

flavor of such leaf is usually better, stronger, and more pronounced than that of tobacco grown in the shade. Flavor and aroma are not considered essential qualities of wrapper tobacco, thinness, elasticity, and burning qualities overweighing them.

The burn of Hawaiian tobacco is exceptionally good, irrespective of whether it is grown in the windward or leeward districts. Burning qualities of the leaf are dependent upon the texture of the soil, its percentage of clay, and its water-holding capacity. The color of the leaf depends upon the time of harvesting and the manipulation in the curing barn. Elasticity is governed in some measure by the period of maturity at which the leaf is harvested. The texture of the leaf—that is, whether it is thin or thick—is governed by the amount of sunshine and the rapidity of growth. The flavor is largely a matter of sunlight. The aroma depends upon the gumminess of the leaf.

In Hawaii the best tobacco districts are in the cloud belts on the slopes of the higher mountains, provided always the rainfall is sufficient. Tobacco of good quality can be grown in the Hamakua, Hilo, Olaa, Puna, Kau, and Kona districts on the island of Hawaii; in Kula, Makawao, and Koolau districts on Maui, and in similar areas on the islands of Lanai, Molokai, Oahu, and Kauai. The best districts are undoubtedly on the larger island. The windward cloud belts there supply a larger rainfall than in the Kau and Kona districts, and will undoubtedly become the best sections for the cultivation of this crop.

It is a popular impression that tobacco will not stand wind, but this is undoubtedly an error. The plant has a very strong tap root, so that it is never blown over, and the leaves do not ordinarily whip or break as would be supposed in the case of so large a leaf. The growing tobacco leaf is pliable and not easily injured.

Hawaii differs in climatic conditions from both Cuba and Sumatra. In Cuba tobacco is grown as a winter crop, being planted from October to December, and harvested in the drier months—from February to April. Tobacco is practically never grown in Cuba during the summer months, which in that part of the world is the season of excessive rains. In Sumatra there are distinct dry and wet seasons. The tobacco is planted at about the end of the wet season, so that it will come to maturity in the early part of the dry season. The Sumatra planting season is from March to May, and the harvesting season from July to September. In Hawaii there is no pronounced wet or dry season, at least not in the windward districts of the islands. This is an advantage in that planting can be made almost continuously throughout the year. Experience indicates that the spring and autumn plantings should be made of the Cuban and the midsummer crops of the Sumatra types. The Cuban will

stand more cold than the Sumatra and is in every way a hardier plant. The rainfall is somewhat higher in Hamakua than it is in the best tobacco districts in Sumatra, but the humidity is higher, and the temperature is lower. It is believed that the uniformity of temperature is advantageous to the production of the highest quality of tobacco, while detrimental to some extent in curing. This can be overcome by artificial means. The factor which is of the greatest importance is undoubtedly that of the prevailing cloudiness. There will be no necessity for artificially shading tobacco in any of our regions of daily cloud accumulation.

PROBLEMS OF TOBACCO CULTURE.

As has been recently pointed out by other investigators, there is a large field for work in the selection and breeding of improved types of tobacco. The crop from almost any lot of seed from whatever source shows the widest possible variation in size, vigor, shape, and quality of plants. Considerable work along this line has already been done, and our results are such that we should advise every tobacco raiser himself to select and breed those types which most completely fulfill the commercial requirements. In working through the fields any plant that shows desirable characteristics should be reserved for seed purposes and protected from cross-fertilization. The leaves should never be cut from a plant that is to be allowed to go to seed.

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